OU3 Wind Tunnel Study

Volume I: Test Report

Prepared for
EG&G Rocky Flats, Inc.

DOE Prime Contract No. DE-AC04-90DP62349
Subcontract No. ASC218973GG
MRI Project No. 3155-M

January 24, 1994

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Volume I: Test Report

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for EG&G Rocky Flats, Inc., under DOE Prime Contract No. DE-AC04-90DP62349 and Subcontract No. ASC218973GG. Mr. Grant Euler was the EG&G project manager.

The project was conducted in MRI's Engineering and Environmental Technologies Department. Dr. Chatten Cowherd served as MRI Project Leader. Other MRI technical staff who contributed to the project were Mary Ann Grelinger (data acquisition), Steve Cummins (wind tunnel operation and laboratory activities), and Alietia Caughron (calculations).

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SECTION 1

INTRODUCTION

Midwest Research Institute (MRI) is pleased to submit this report documenting portable wind tunnel tests that were conducted to quantify wind resuspension emissions of particulate matter from the soils and sediments of Operable Unit Three (OU3) of the Rocky Flats Plant near Golden, Colorado. The test sites were concentrated within three locations: the shore around Standley Reservoir, the shore around Great Western Reservoir, and the terrestrial sites between the two. A map of the test sites is shown in Figure 1-1.

This report describes the sampling equipment and procedures that were used in the field testing and the results obtained. Further description of the test sites and other technical background information for this study are provided in *Technical Memorandum No. 1 to the Final RFI/RI Work Plan: Operable Unit No. 3* (U.S. Dept. of Energy, 1993).

The body of this report is organized as follows:

- Section 2 describes the equipment and procedures used for field sampling and analysis.

- Section 3 describes the types of tests performed and the levels of disturbance applied to the test surfaces.

- Section 4 presents the test results and assesses the quality of the test data.

- Section 5 lists the literature references.

The field data sheets generated during this study are incorporated into Volume II of this report.

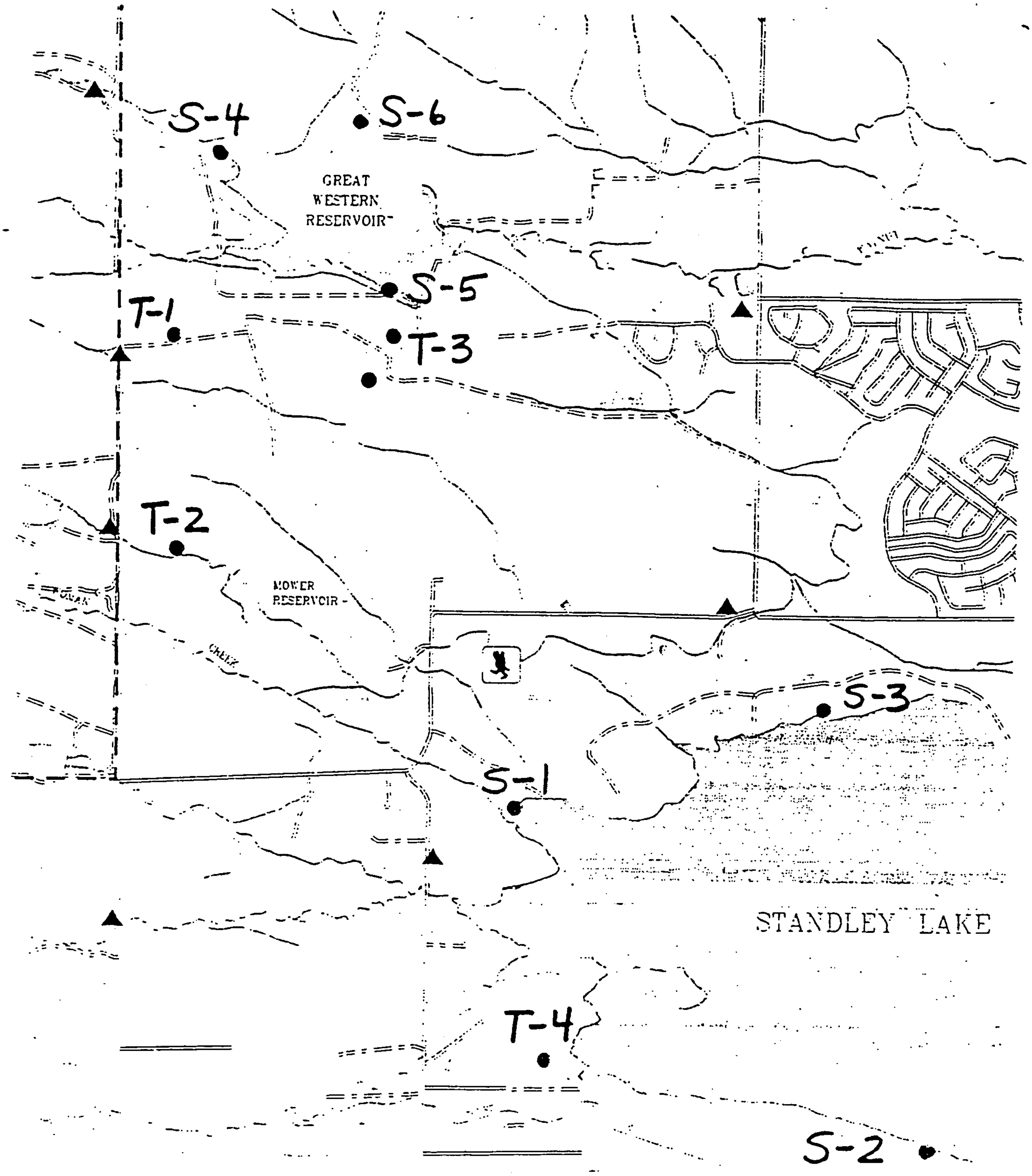

Figure 1-1. Rocky Flats OU3 air sampling test sites.

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SECTION 2

SAMPLING/ANALYSIS EQUIPMENT AND PROCEDURES

The MRI portable pull-through wind tunnel, as described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites* (EPA, 1989), was used in performing the proposed field studies. The MRI wind tunnel (Figure 2-1) features all of the required design and operating characteristics, including the equipment for extracting isokinetic samples of wind generated particulate matter, for mass emissions and particle size determination. It is powered by a gasoline engine with direct mechanical linkage to the primary blower, which pulls the airflow through the tunnel.

In operating the wind tunnel, the open-floored test section is placed directly over the surface to be tested. Air is drawn through the tunnel at controlled velocities. The exit air stream from the test section passes through a circular duct fitted with a sampling probe near the downstream end. Air is drawn through the probe by a high-volume sampling train. Interchangeable probe tips are sized for isokinetic sampling.

A high-volume ambient air sampler is operated near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. By sampling under light ambient wind conditions, background interferences from upwind erosion sources can be minimized.

The wind tunnel method relies on a straightforward mass balance technique for calculation of emission rate. No assumptions about plume configuration are required.

This technique provides for precise study of the wind erosion process on specific test surfaces and for a wide range of wind speeds. Previous wind erosion studies using the MRI wind tunnel have led to the EPA recommended emission factors

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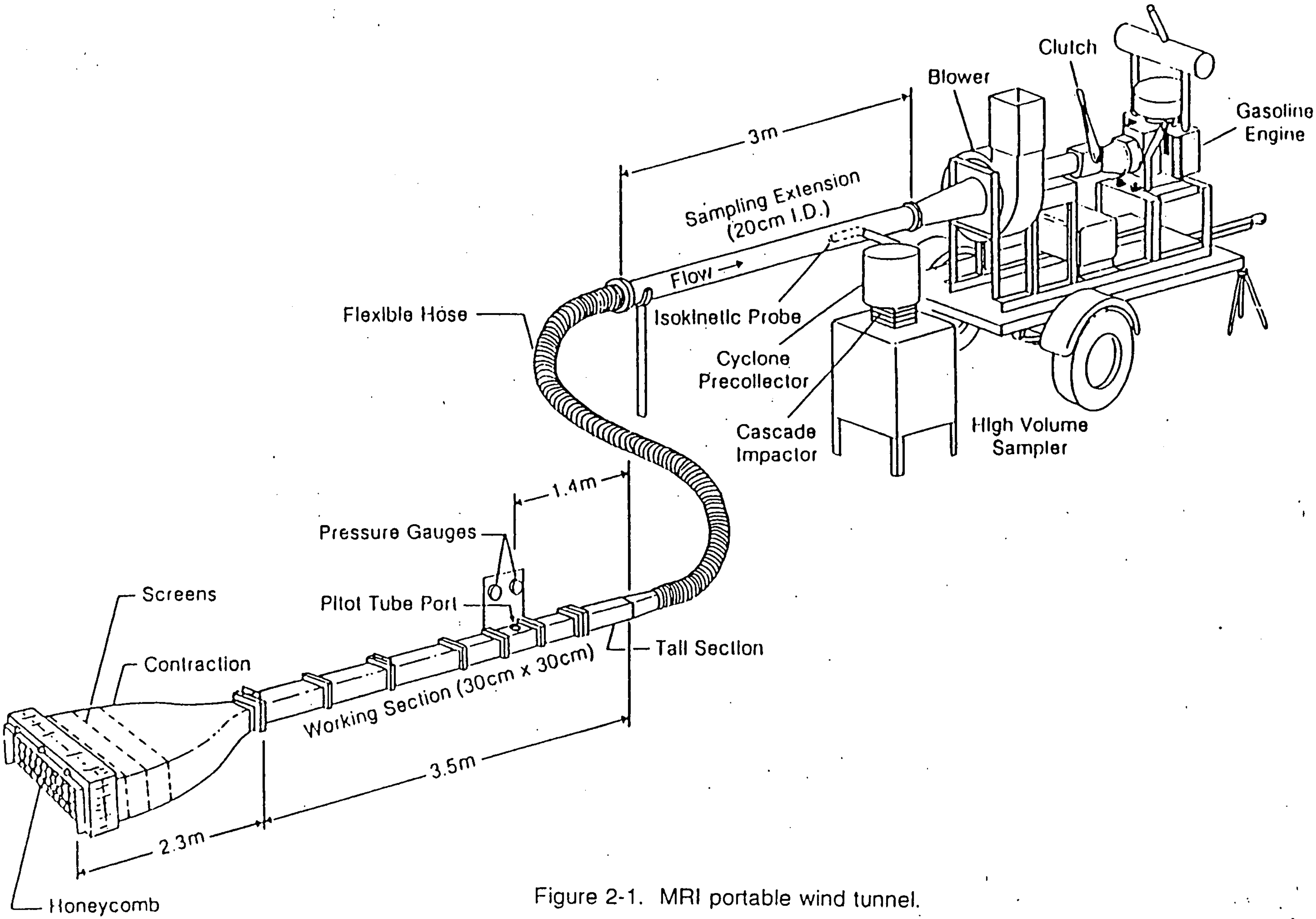

Figure 2-1. MRI portable wind tunnel.

presented in *Compilation of Air Pollutant Emission Factors (AP-42)*, published by U.S. EPA (1985).

2.1 SAMPLING EQUIPMENT

The MRI wind tunnel is identical in design to that developed by Gillette (1978) but is nearly twice as large. It consists of a two-dimensional 5:1 contraction section, an open-floored test section, and a roughly conical diffuser. The larger test area of this tunnel (30 cm × 3.5 m) provides for its use on rougher surfaces. The tunnel centerline airflow is adjustable up to an approximate maximum speed of nearly 19 m/s (40 mph), as measured by a pitot tube at the downstream end of the test section.

Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence. It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms.

The wind speed profile near the test surface (tunnel floor) and the walls of the tunnel have been shown to follow a logarithmic distribution.

$$u(z) = \frac{u*}{0.4} \ln \frac{z}{z_o} \qquad (1)$$

where:
- u = wind speed, cm/s
- $u*$ = friction velocity, cm/s
- z = height above test surface, cm
- z_o = roughness height, cm

The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement. As indicated from Equation 1, the wind velocity at any fixed height above the surface (but below the centerline of the wind tunnel) is proportional to the friction velocity. The roughness height of each test surface is determined by extrapolation of the logarithmic wind speed profile near the surface to $u = 0$.

An emissions sampling module provides for representative extraction and aerodynamic sizing of particulate emissions generated by wind erosion. The sampling module is located between the tunnel outlet hose and the fan inlet. The particulate sampling train, which is operated at 34 to 69 m^3/h (20 to 40 acfm), consists of a tapered probe, cyclone precollector, parallel-slot cascade impactor (optional), backup filter, and high-volume motor. The sampling intake is pointed into the air stream, and the sampling velocity adjusted to the approach air speed by fitting the intake with a nozzle of appropriate size.

When operated at 69 m^3/h (40 acfm), the cyclone has an approximate cutpoint of 10 μmA, based on laboratory calibration (Baxter et al., 1986). Thus the particulate fraction that penetrates the cyclone constitutes PM-10.

When additional particle sizing is required, a high-volume cascade impactor with glass fiber impaction substrates is inserted between the cyclone and the back-up filter (as shown in Figure 2-2), and the sampling train is operated at 34 m^3/h (20 acfm). The cyclone preseparator is used to remove coarse particles that otherwise would be subject to particle bounce within the impactor, causing fine particle bias. At the 20 acfm flow rate, the cyclone has a cutpoint of approximately 15 μmA, based on laboratory calibration (Baxter et al., 1986). The use of greased glass fiber substrates mitigates against residual particle bounce and provides for direct gravimetric analysis of the particulate catches without the need to remove and separate them from the substrates.

A pitot tube is used to measure the centerline wind speed in the sampling duct, upstream of the point where the sampling probe is installed. The volumetric flow rate through the wind tunnel is determined from a published relationship (Owen and Pankhurst, 1969) between the centerline (maximum) velocity in a circular duct and the average velocity, as a function of Reynolds' number. Because the ratio of the centerline wind speed in the sampling duct to the centerline wind speed in the test section is nearly independent of flow rate, the ratio can be used to determine isokinetic sampling conditions for any flow rate in the tunnel.

A portable high-volume air sampler with an open-faced filter is operated on top of the tunnel inlet section to measure background dust levels. The filter is vertically oriented parallel to the tunnel inlet face.

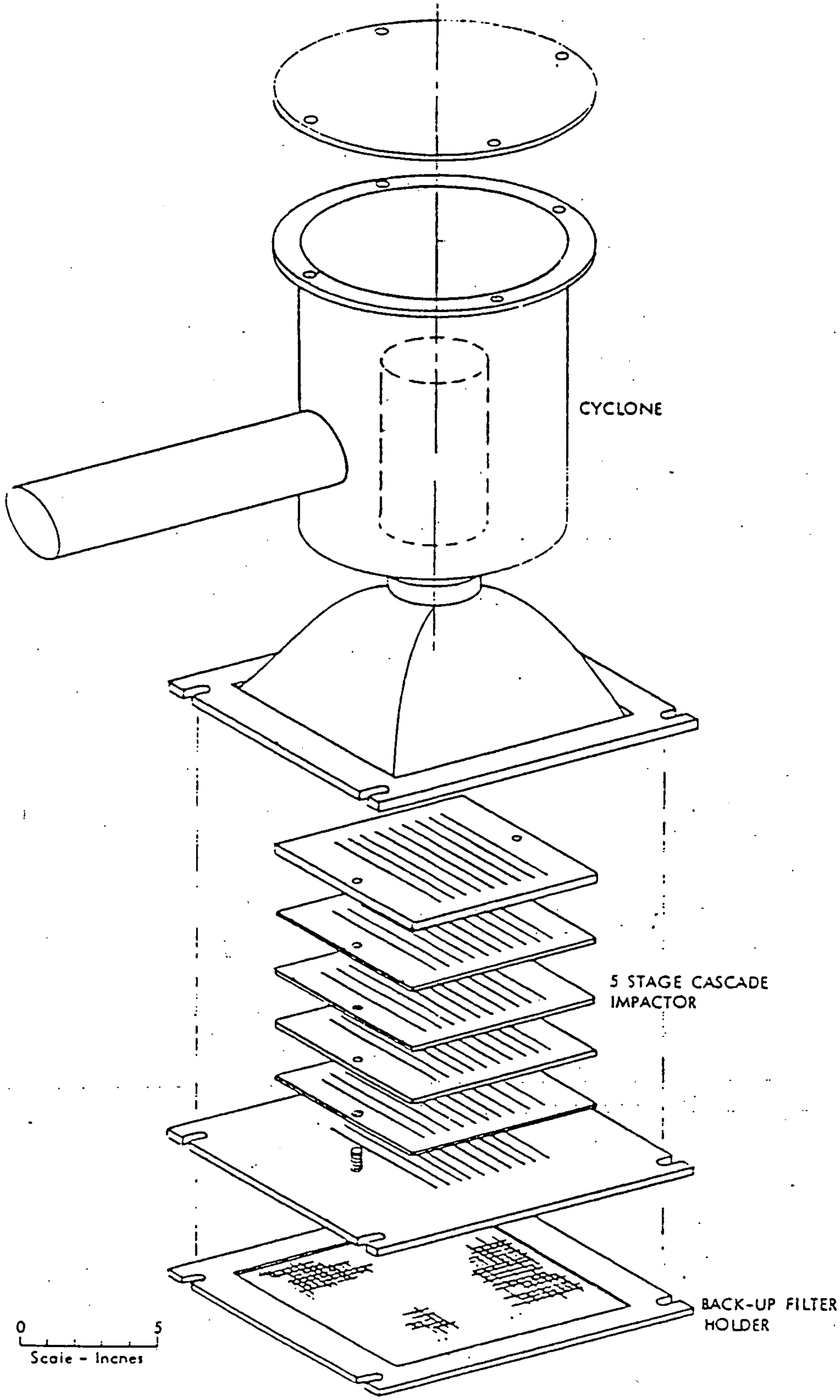

Figure 2-2. Particulate collection devices.

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2.2 SAMPLING PROCEDURE

Prior to each test series, the test section of the tunnel is placed directly on the selected test surface. Care is taken not to disturb any natural crust that might be present. To prevent air infiltration under the sides of the open-floored section, the rubberized skirts, which are attached to the bottom edges of the tunnel sides, are stretched out on the surface adjacent to the test surface. Rubber tubes filled with sand are laid along the skirts to assure a tight seal.

With the tunnel in place, the airflow is gradually increased up to the threshold for the onset of wind erosion, as determined by visual observation of migration of coarse particles, and then reduced slightly. At the sub-threshold flow, a wind speed profile is measured and a roughness height is determined. The measured roughness height allows for conversion of the tunnel centerline wind speed to the equivalent friction velocity using the logarithmic wind speed profile. A separate areawide roughness height reflecting the larger terrain features is used to convert the tunnel centerline wind speed to the equivalent wind speed at a standard 10-m height.

Sampling is initiated just after the tunnel centerline wind speed reaches the first prescribed super-threshold level corresponding to the desired friction velocity or wind speed corrected to a height of 10 m. After the prescribed sampling period, the flow is shut off and the particulate samples removed (cyclone catch, impaction substrates [optional], and backup filter). Then with the tunnel in the same position, testing may be conducted separately at the same flow rate to determine whether the erosion rate is decaying in the manner of a "limited reservoir" surface (Cowherd, 1993). Again with the tunnel still in the same position, testing may be conducted at a higher flow rate. Additional tests of the same surface may be performed at successively higher wind speeds up to the flow capacity of the tunnel.

At the end of each test, the sampling train is disassembled and taken to the field instrument van, and the collected samples of dust emissions are carefully placed in protective containers. After transfer of samples to a laboratory setting, high-volume filters and impaction substrates are placed in individual protective envelopes or in specially designed carrier cases. Dust is transferred from the cyclone precollector by brushing it into a tared clear, resealable plastic pouch.

Dust samples from the field tests are returned to an environmentally controlled laboratory for gravimetric analysis. Glass fiber filers and impaction substrates are conditioned at constant temperature and relative humidity for 24 h prior to weighing (the same conditioning procedure as used before taring). The particulate catch from the cyclone precollector is weighed in the tared pouch.

The raw test data that are recorded include the following:

Site code and description
Test date, run number, and type of test
Start time and sampling duration
Threshold wind speed at tunnel centerline
Subthreshold wind speed profile
Operating wind speeds at tunnel centerline and at centerline of sampling tube
Sampling module flow rate
Ambient meteorology (wind speed and direction; temperature; barometric pressure)

2.3 TEST RESULTS AND INTERPRETATION

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from the surface is proportional to the amount of erodible material remaining:

$$\frac{dM}{dt} = -kM \tag{2}$$

where: M = quantity of erodible material present on the surface at any time, g/m^2
k = constant, s^{-1}
t = cumulative erosion time, s

Integration of Equation 2 yields:

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$$M = M_o e^{-kt} \quad (3)$$

where: M_o = erosion potential, i.e., quantity of erodible material present on the surface before the onset of erosion, g/m^2

Consistent with Equation 3, the erosion potential at a given wind speed may be calculated from the losses of erodible material from the test surface for two erosion times:

$$\frac{\ln\left[\frac{M_o - L_1}{M_o}\right]}{\ln\left[\frac{M_o - L_2}{M_o}\right]} = \frac{t_1}{t_2} \quad (4)$$

where: L_1 = mass loss during time period 0 to t_1, g/m^2
L_2 = mass loss during time period 0 to t_2, g/m^2

The loss of erodible material (g/m^2) which occurs during a test is calculated as follows:

$$L = \frac{CQt}{A} \quad (5)$$

where: C = average particulate concentration in tunnel exit stream (after subtraction of background concentration), g/m^3
Q = tunnel flow rate, m^3/s
A = exposed test surface area = 0.918 m^2

An iterative procedure is required to calculate erosion potential from Equation 4 after substitution of two cumulative loss values and erosion times obtained from back-to-back testing of the same surface at the specified wind speed.

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on. This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses wold have occurred at the higher speeds.

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Based on field tests of erodible crustal materials (measured mostly at surface coal mines), the erosion potential function for a dry exposed surface has been found to have the following form (Cowherd, 1988):

$$M_o = 58(u^* - u_t^*)^2 + 25(u^* - u_t^*) \quad (6)$$

$$= 0 \text{ for } u^* \leq u_t^*$$

where: u^* = friction velocity (m/s)
u_t^* = threshold friction velocity (m/s)

It provides the basis for the EPA method of estimating emissions from "industrial wind erosion."

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action which results in the exposure of fresh surface material. On a land surface, this would occur whenever soil is either added to or removed from the old surface, or whenever surface material is turned over to a depth exceeding the size of the largest pieces of aggregate present in the soil. In the absence of such anthropogenic disturbances, it is usually assumed that natural "weathering" (e.g., vegetative growth cycles, freezing/thawing) creates the equivalent of one disturbance per year. The effects of animals frequently moving over the surface may cause the equivalent of additional annual disturbances.

In summary, the calculated test results for each test surface and wind speed include:

Roughness height
Friction velocity
Equivalent wind speed at reference 10-m height
Average emission rate
Erosion potential (for "limited reservoir" surfaces)

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SECTION 3

SAMPLING PROTOCOL

This section describes the types of tests performed to characterize the subject soils and sediments under various levels of surface disturbance.

3.1 TEST TYPE

Two types of tests were performed in this study: screening tests and comprehensive tests. A screening test entails an emission measurement for a 20-min sampling period with the wind tunnel operating near its flow capacity. The purpose of a screening test is to bracket the worst-case erodibility of representative portions of the study area with different surface characteristics (soil texture, presence of nonerodible elements, etc.).

During a screening test, only a cyclone and a backup filter are used on the sampling train. The sampling train is operated at 40 acfm so that the cyclone cutpoint is approximately 10 μmA. This provides for separation of particulate emissions into two particle size fractions: total particulate matter* (TP) and PM-10.

For a comprehensive test (series), the wind tunnel is operated at two flow rates: approximately one-third and two-thirds of the range between the threshold velocity (for the specific test surface) and the capacity of the wind tunnel. At each flow, a 2-min test is followed by an 8-min test so that the decay in the emission rate can be determined and the erosion potential calculated directly.

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* Because of the typically high tunnel flow velocities, a large mass fraction of the particulate emissions usually exceeds the 30-μmA cutpoint frequently associated with the standard high-volume sampler; particles captured by a standard high-volume sampler are frequently referred to as "total suspended particulate" matter.

For the comprehensive tests, a three-stage cascade impactor is used in the sampling train which is operated at 20 acfm. At that flow rate, the cutpoint of the cyclone precollector is approximately 15 μmA, and the cutpoint of the first impaction stage is approximately 10 μmA.

3.2 SURFACE DISTURBANCE LEVELS

The surface erodibilities of sampling sites within the three test locations were affected either by natural mitigative influences of vegetation and crusting (terrestrial sites) or by long-term consolidation of surface material (shoreline sites). In addition to erodibility testing of these surfaces in their undisturbed condition, it was of interest to test the surface materials without the protective influences. This was accomplished as follows.

At the shoreline sites, two levels of disturbance were imposed. The first involved manually raking the surface to a depth of 1 to 2 in. This activity resulted in loosening of the surface "crust," but it left nonerodible chunks of material on the surface. The second level of disturbance involved driving over the surface with a minivan or pickup truck to create surface material that was pulverized to a depth of at least 1 in.

At the terrestrial sites, the same two types of disturbance were imposed, but only after all vegetation had been cut at ground level and removed. It should be noted that the buried root systems that were left behind continued to bind surface material with a resulting protective effect. Figure 3-1 shows typical vegetation types that were present along with other vegetation at each of the terrestrial sites. The frame on this figure represents the 30 × 30 cm cross section of the tunnel working section.

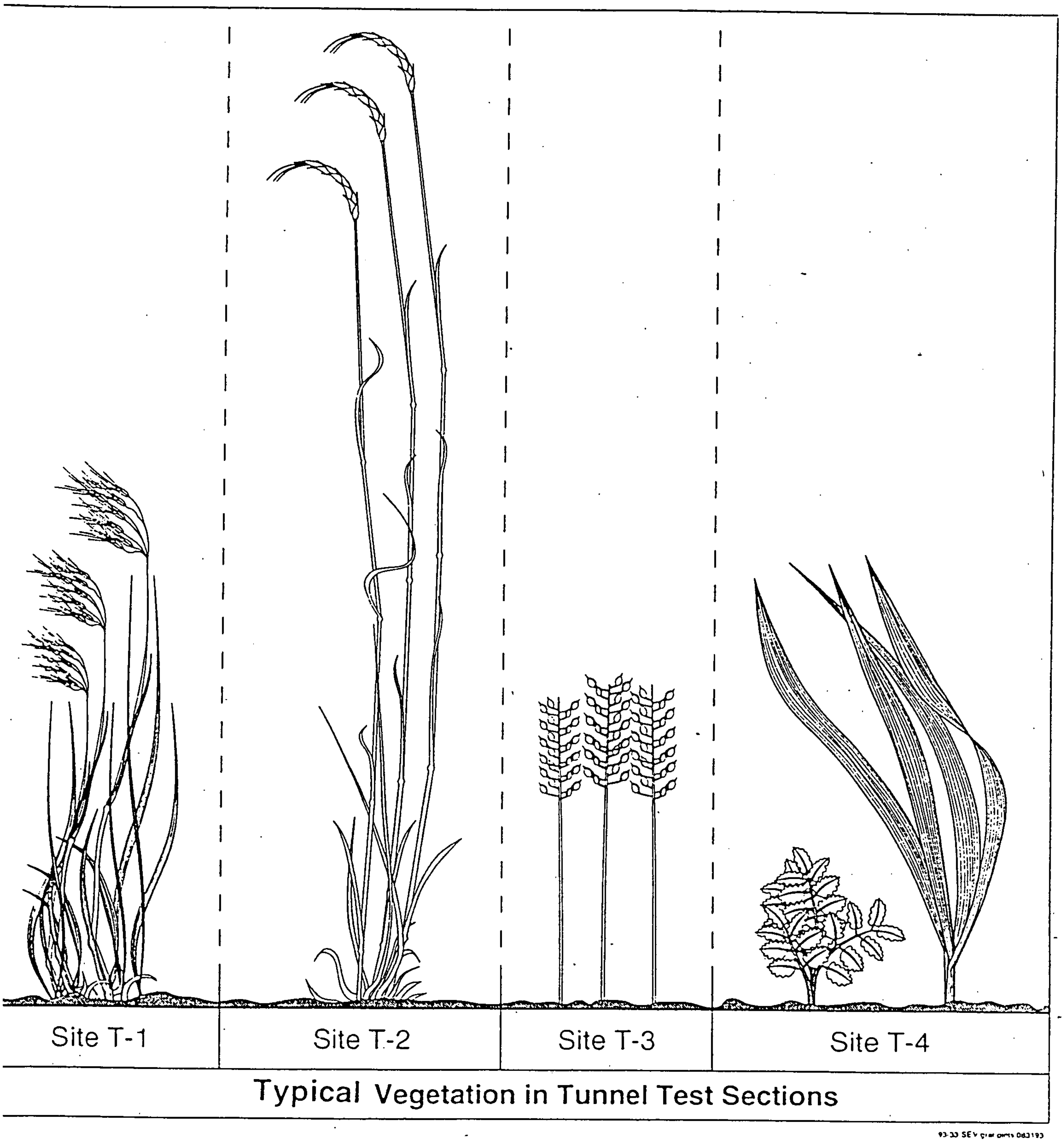

Figure 3-1. Typical vegetation at terrestrial sites
(figure frame represents 30 × 30 cm tunnel cross section).

SECTION 4

TEST RESULTS

A total of 15 screening tests and 8 comprehensive test series (32 individual tests) were performed in this study. These tests took place during two field trips: June 2 through 10, 1993, and July 8 through 10, 1993. During the first field trip, large shoreline areas of the Great Western Reservoir (GWR) were above the water level and were available for testing. However, during the period between the first and second field trips, the water level of both the GWR and Standley Lake rose substantially covering most shoreline sites and preventing further testing. Testing during the second trip focused on characterizing the much larger terrestrial area. The shoreline sites were believed to have been adequately characterized during the first field trip.

Table 4-1 lists the site parameters for each of the tests including site identity, level of disturbance and ambient conditions. All of the four originally designated terrestrial sites were tested, and three of the six originally designated shoreline sites were tested. Every site selected for testing was tested in its undisturbed condition and with one or more levels of disturbance. Comprehensive tests were performed only on disturbed surfaces. Ambient temperatures (°F) varied from the 60's and lower 70's during the June testing to the 70's and 80's during the July testing. All tests were performed on dry surfaces as determined by EG&G Rocky Flats personnel.

Table 4-2 shows the quantitative measures of surface erodibility for each test site including the thresholds for wind erosion and the roughness heights of each surface. As expected, the vegetation and imbedded rocks of the terrestrial sites created greater roughness than was found at the shoreline sites. Correspondingly, the highest threshold velocities were found on the vegetated terrestrial sites without any surface disturbance, while the lowest threshold velocities were found at the highly disturbed shoreline sites, especially at the Walnut Creek inlet to GWR.

TABLE 4-1. TEST SITE PARAMETERS

Date	Run No.	Site ID	Location	U/D/ Dx*	Start time	Sampling duration (min)	Ambient meteorology Temp. (°F)	Barom. pressure (in. Hg)
6/2/93	RF-1	S-6	North shore of G W Reservoir	U	15:42:00	20	75	24.0
6/2/93	RF-2	S-6	North shore of G W Reservoir	D	16:56:00	20	70	24.0
6/4/93	RF-3	S-4	Walnut Creek inlet to G W Reservoir	U	13:57:00	20	60	24.6
6/4/93	RF-4	S-4	Walnut Creek inlet to G W Reservoir	D	15:25:00	20	68	24.5
6/4/93	RF-5	S-4	Walnut Creek inlet to G W Reservoir	Dx	19:20:00	20	57	24.3
6/5/93	RF-6	S-4	Walnut Creek inlet to G W Reservoir	Dx				
	a				11:58:00	3	69	24.3
	b				12:16:30	7	69	24.3
	c				12:36:30	2	69	24.3
	d				12:51:00	8	69	24.3
6/5/93	RF-7	T-1	Mesa SW of G W Reservoir	U	18:47:00	20	69	24.0
6/6/93	RF-8	T-1	Mesa SW of G W Reservoir	D	16:56:30	20	70	24.0
6/6/93	RF-9	T-3	Mesa S of G W Reservoir	U	19:30:45	20	66	24.0
6/7/93	RF-10	T-3	Mesa S of G W Reservoir	D	09:31:30	20	54	24.0
6/9/93	RF-11	T-2	Hillside above Mower Reservoir	U	10:21:20	20	70	24.5
6/9/93	RF-12	T-2	Hillside above Mower Reservoir	D	11:56:55	20	74	24.5
6/9/93	RF-13	T-2	Hillside above Mower Reservoir	D				
	a				17:54:42	2	67	24.3
	b				18:08:18	8	67	24.3
	c				18:24:50	2	67	24.3
	d				18:35:56	8	67	24.3
6/10/93	RF-14	S-3	North shore of Standley Lake	U	10:02:45	20	71	24.6

TABLE 4-1 (Continued)

Date	Run No.	Site ID	Location	U/D/ Dx*	Start time	Sampling duration (min)	Ambient meteorology Temp . (°F)	Barom. pressure (in. Hg)
6/10/93	RF-15	S-3	North shore of Standley Lake	D	11:30:40	20	73	24.6
6/10/93	RF-16	T-4	Hillside to SW of Standley Lake	U	16:18:40	20	76	24.4
6/10/93	RF-17	T-4	Hillside to SW of Standley Lake	D	17:52:15	20	76	24.5
7/8/93	RF-18	T-1	Mesa SW of G W Reservoir	D				
	a				10:25:10	2	78	24.1
	b				10:34:25	8	78	24.1
	c				10:58:00	2	82	24.1
	d				11:06:47	8	82	24.1
7/9/93	RF-19	T-1	Mesa SW of G W Reservoir	Dx				
	a				08:46:25	2	68	24.3
	b				08:54:10	8	68	24.3
	c				09:14:03	2	71	24.3
	d				09:23:41	8	71	24.3
7/9/93	RF-20	T-2	Hillside above Mower Reservoir	D				
	a				14:19:53	2	83	24.4
	b				14:36:38	8	83	24.4
	c				15:01:36	2	82	24.4
	d				15:11:49	8	82	24.4
7/10/93	RF-21	T-2	Hillside above Mower Reservoir	Dx				
	a				08:45:18	2	72	24.3
	b				08:53:21	8	72	24.3
	c				09:11:45	2	78	24.3
	d				09:20:41	8	78	24.3

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TABLE 4-1 (Continued)

Date	Run No.	Site ID	Location	U/D/ Dx*	Start time	Sampling duration (min)	Ambient meteorology	
							Temp . (°F)	Barom. pressure (in. Hg)
7/10/93	RF-22	T-3	Mesa S of G W Reservoir	D				
	a				13:52:10	2	86	24.3
	b				13:59:15	8	86	24.3
	c				14:19:50	2	86	24.3
	d				14:29:50	8	86	24.3
7/10/93	RF-23	T-3	Mesa S of G W Reservoir	Dx				
	a				15:40:59	2	90	24.2
	b				16:49:25	8	90	24.2
	c				17:08:20	2	90	24.2
	d				17:15:33	8	90	24.2

* U/D/Dx = Undisturbed/Disturbed/Extra disturbed

TABLE 4-2. TEST SURFACE CONDITIONS

Run No.	Site ID	U/D/Dx*	Roughness height (z_o)	Threshold velocity at tunnel CL (m/s)	Threshold velocity at tunnel CL (mph)	Threshold friction velocity (cm/s)	Equivalent threshold velocity at 10 m (mph)
RF-1	S-6	U	0.012	12	27	67	76
RF-2	S-6	D	0.025	6.2	14	38	39
RF-3	S-4	U	0.047	15	34	100	95
RF-4	S-4	D	0.070	5.7	13	43	37
RF-5	S-4	Dx	0.00042	4.8	11	18	31
RF-6	S-4	Dx	0.00006	4.4	10	14	28
RF-7	T-1	U	1.0	> 19	> 43	> 280	> 121
RF-8	T-1	D	0.80	8.8	20	120	56
RF-9	T-3	U	0.34	> 17	> 39	> 180	> 110
RF-10	T-3	D	0.065	10	23	74	65
RF-11	T-2	U	0.65	> 14	> 31	> 170	> 87
RF-12	T-2	D	0.075	11	26	86	73
RF-13	T-2	D	0.28	9.7	22	97	62
RF-14	S-3	U	0.0010	11	24	44	67
RF-15	S-3	D	0.060	11	25	79	70
RF-16	T-4	U	0.45	> 14	> 32	> 160	> 90
RF-17	T-4	D	0.12	10	23	84	65
RF-18	T-1	D	0.16	8.4	19	73	53
RF-19	T-1	Dx	0.015	5.7	13	33	37
RF-20	T-2	D	0.13	9.2	21	78	59
RF-21	T-2	Dx	0.038	7.9	18	53	51
RF-22	T-3	D	0.15	8.8	20	76	56
RF-23	T-3	Dx	0.014	6.2	14	35	39

* U/D/Dx = Undisturbed/Disturbed/Extra disturbed

The undisturbed terrestrial sites all exhibited threshold velocities exceeding 80 mph at the 10-m reference height, partially due to the presence of rocks imbedded in the surface.

Table 4-3 lists the wind tunnel test conditions. The surfaces were tested at 10-m equivalent wind velocities ranging from 48 mph (Site S-4, Dx) to more than 110 mph (Site S-6, U). The equivalent wind velocity at the 10-m reference height equals 2.8 times the velocity of the wind tunnel centerline, based on a macro-scale roughness height of 1.5 cm for the Rocky Flats area as determined by Hodgin (Hodgin, 1982).

Table 4-4 presents the emission rates (all tests) and erosion potentials (comprehensive test series only) that were quantified in this study. Based on the recent results of replicate emission characterization of a defined test material (Cowherd, 1993), the precision of erosion potential measurements with the MRI portable wind tunnel may be expressed in terms of a relative standard deviation of 14 percent.

The most erodible surface was found at Site S-4 (Walnut Creek inlet to Great Western Reservoir) where a large area of silt had been deposited on top of the rocky sediment present on the rest of the shoreline. Unlike the other test surfaces, this surface was relatively uncompacted. As expected, emissions from all tested surfaces increased substantially with the level of disturbance.

The functional relationship given earlier for erosion potential vs friction velocity (Equation 6) was developed primarily from the testing of surface materials (coal, overburden, etc.) at western surface coal mines. This relationship is plotted in Figure 4-1, along with the data points obtained from the present study. It is clear from the figure that the measured erosion potentials for moderately disturbed surfaces at the OU3 test sites are well under the values that would be predicted by the functional relationship for "industrial wind erosion." With the exception of two tests, even the erosion potential values for highly disturbed surfaces tested within OU3 are substantially less than the values predicted by the relationship.

Table 4-5 gives the mass emission rates for various particle size subfractions of PM-10. Table 4-6 expresses the subfractions of PM-10 as weight percentages of TP. As indicated in Figure 4-2, the observed ratio of PM-10 to TP was higher on the terrestrial surfaces than on the shoreline surfaces. In addition, the ratio tended to decrease with level of disturbance, indicating that the increase in the wind-generated TP emissions was higher than the increase in PM-10 emissions when the surface was disturbed.

TABLE 4-3. WIND TUNNEL TEST CONDITIONS

Run No.	S/C**	Site ID	U/D/Dx*	Tunnel CL wind velocity (mph)	Friction velocity (cm/s)	Equivalent wind velocity at 10 m (mph)
RF-1	S	S-6	U	39.7	98	110
RF-2	S	S-6	D	30.3	83	85
RF-3	S	S-4	U	34.1	100	96
RF-4	S	S-4	D	28.9	95	81
RF-5	S	S-4	Dx	32.0	54	90
RF-6	C	S-4	Dx			
a				17.1	24	48
b				17.1	24	48
c				23.7	34	67
d				23.7	34	67
RF-7	S	T-1	U	34.3	220	96
RF-8	S	T-1	D	33.2	200	93
RF-9	S	T-3	U	25.3	120	71
RF-10	S	T-3	D	32.5	100	91
RF-11	S	T-2	U	25.4	140	71
RF-12	S	T-2	D	30.6	100	86
RF-13	C	T-2	D			
a				23.1	100	65
b				23.1	100	65
c				27.8	120	78
d				27.8	120	78
RF-14	S	S-3	U	32.2	59	90
RF-15	S	S-3	D	34.2	110	96
RF-16	S	T-4	U	37.1	180	100
RF-17	S	T-4	D	33.6	120	94
RF-18	C	T-1	D			
a				24.0	93	67
b				24.0	93	67
c				28.1	110	79
d				28.1	110	79

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TABLE 4-3 (Continued)

Run No.	S/C**	Site ID	U/D/Dx*	Tunnel CL wind velocity (mph)	Friction velocity (cm/s)	Equivalent wind velocity at 10 m (mph)
RF-19	C	T-1	Dx			
a				23.7	60	67
b				23.7	60	67
c				27.7	70	78
d				27.7	70	78
RF-20	C	T-2	D			
a				27.0	100	76
b				27.0	100	76
c				31.1	110	87
d				31.1	110	87
RF-21	C	T-2	Dx			
a				24.0	71	67
b				23.8	71	67
c				31.0	91	87
d				31.0	91	87
RF-22	C	T-3	D			
a				26.2	100	74
b				26.2	100	74
c				34.0	130	95
d				34.0	130	95
RF-23	C	T-3	Dx			
a				24.2	61	68
b				24.2	61	68
c				34.2	86	96
d				34.2	86	96

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TABLE 4-4. TEST RESULTS

Run No.	Site ID	U/D/Dx*	Emission rate: Suspended particulate (mg/m²-sec)	Emission rate: PM-10 (mg/m²-sec)	Emission rate: Ratio PM-10/SP	Erosion potential of PM-10 (g/m²)
RF-1	S-6	U	2.17	0.059	0.027	-
RF-2	S-6	D	211	0.41	0.0019	-
RF-3	S-4	U	2.45	**	0	-
RF-4	S-4	D	180	1.4	0.0077	-
RF-5	S-4	Dx	8,590	100	0.012	-
RF-6	S-4	Dx				
a			2,410	7.2	0.0030	1.61
b			220	0.72	0.0033	
c			17,800	76	0.0043	28.8
d			5,054	30	0.0060	
RF-7	T-1	U	0.58	0.11	0.19	-
RF-8	T-1	D	1.45	0.081	0.056	-
RF-9	T-3	U	0.24	0.22	0.89	-
RF-10	T-3	D	16.2	1.5	0.094	-
RF-11	T-2	U	0.16	0.025	0.16	-
RF-12	T-2	D	11.6	0.11	0.0093	-
RF-13	T-2	D				
a			28.4	1.5	0.054	0.357
b			1.44	0.34	0.24	
c			25.0	0.74	0.030	0.703
d			4.49	0.37	0.083	
RF-14	S-3	U	2.44	**	0	-
RF-15	S-3	D	9.98	0.075	0.0075	-
RF-16	T-4	U	0.48	0.012	0.025	-
RF-17	T-4	D	40.1	0.33	0.0081	-
RF-18	T-1	D				
a			6.79	0.20	0.030	0.034
b			1.27	0.020	0.016	
c			13.7	0.38	0.028	0.109
d			2.05	0.061	0.030	

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TABLE 4-4 (Continued)

Run No.	Site ID	U/D/Dx*	Emission rate: Suspended particulate (mg/m^2-sec)	Emission rate: PM-10 (mg/m^2-sec)	Emission rate: Ratio PM-10/TP	Erosion potential of PM-10 (g/m^2)
RF-19	T-1	Dx				
a			231	4.5	0.020	1.12
b			20.1	1.1	0.056	
c			181	3.6	0.020	2.04
d			41.0	0.89	0.022	
RF-20	T-2	D				
a			22.8	0.66	0.029	0.150
b			1.43	0.14	0.098	
c			35.6	0.66	0.019	0.298
d			3.87	0.14	0.035	
RF-21	T-2	Dx				
a			103	0.77	0.0074	0.182
b			5.20	0.18	0.034	
c			988	2.1	0.0021	0.694
d			40.0	0.51	0.013	
RF-22	T-3	D				
a			8.67	0.26	0.029	0.039
b			1.02	0.017	0.016	
c			46.9	1.0	0.022	0.261
d			9.13	0.20	0.022	
RF-23	T-3	Dx				
a			312	12	0.038	2.95
b			26.2	2.9	0.11	
c			1,140	47	0.042	14.7
d			66.6	12	0.17	

* U/D/Dx = Undisturbed/Disturbed/Extra disturbed
** Emissions are not distinguishable from the background.

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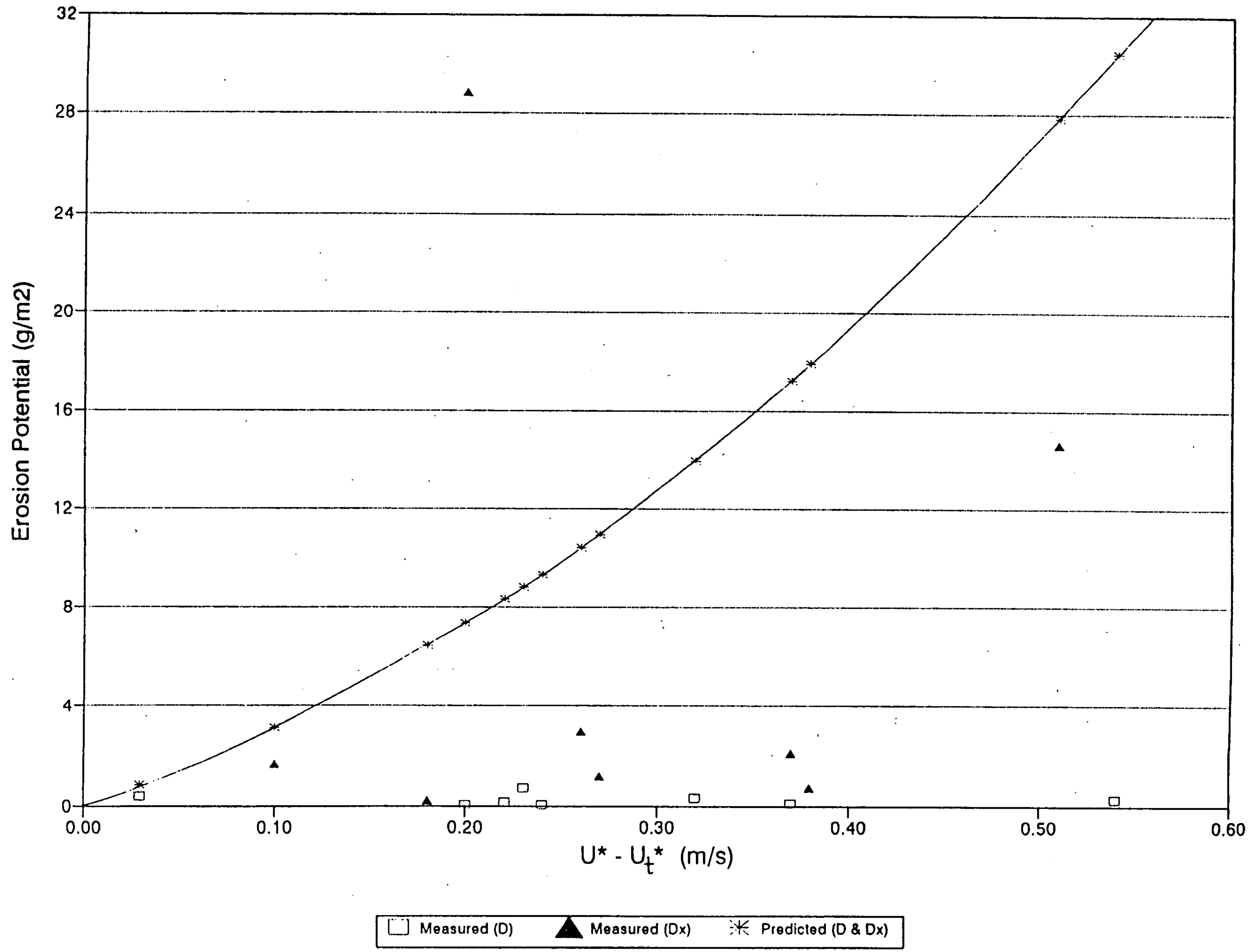

Figure 4-1. Comparison of the measured erosion potential to the curve developed for industrial wind erosion.

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TABLE 4-5. MASS EMISSION RATES ($\mu g/m^2$-sec) FOR DIFFERENT PARTICLE SIZES

Run No.	4.2 μg-< 10.1 μg	2.1 μg-< 4.2 μg	< 2.1 μg	Total PM-10
RF-6a	3.48	1.72	2.03	7.2
RF-6b	0.344	0.108	0.272	0.72
RF-6c	42.2	14.5	19.8	77
RF-6d	13.4	5.14	11.7	30
RF-13a	0.710	0.685	0.128	1.5
RF-13b	0.138	0.169	0.035	0.34
RF-13c	0.311	0.394	0.039	0.74
RF-13d	0.153	0.152	0.069	0.37
RF-18a	•	•	0.217	0.20
RF-18b	•	•	0.044	0.02
RF-18c	0.030	•	0.361	0.38
RF-18d	•	•	0.079	0.061
RF-19a	1.73	1.19	1.61	4.5
RF-19b	0.428	0.294	0.399	1.1
RF-19c	1.56	0.780	1.28	3.6
RF-19d	0.384	0.191	0.313	0.89
RF-20a	0.066	0.002	0.593	0.66
RF-20b	0.007	•	0.140	0.14
RF-20c	0.035	0.002	0.623	0.66
RF-20d	•	•	0.146	0.14
RF-21a	0.248	0.285	0.232	0.77
RF-21b	0.056	0.067	0.053	0.18
RF-21c	0.869	0.615	0.613	2.1
RF-21d	0.210	0.149	0.147	0.51
RF-22a	0.157	•	0.114	0.26
RF-22b	0.020	•	0.013	0.017
RF-22c	0.503	0.260	0.263	1.0
RF-22d	0.102	0.050	0.045	0.20
RF-23a	5.04	2.75	4.15	12
RF-23b	1.24	0.675	1.02	2.9
RF-23c	19.3	11.3	16.7	47
RF-23d	4.75	2.77	4.10	12

• Calculated results are slightly negative due to corrections for background concentrations.

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TABLE 4-6. WEIGHT PERCENTS (%) OF PARTICULATE EMISSIONS

Run No.	4.2 μg- < 10.1 μg	2.1 μg- < 4.2 μg	< 2.1 μg	Total PM-10
RF-6a	0.145	0.0716	0.0843	0.30
RF-6b	0.156	0.0489	0.124	0.33
RF-6c	0.236	0.0812	0.111	0.43
RF-6d	0.266	0.102	0.121	0.60
RF-13a	2.50	2.41	0.451	5.36
RF-13b	9.57	11.7	2.41	24
RF-13c	1.25	1.58	0.156	3.0
RF-13d	3.39	3.38	1.53	1.6
RF-18a	•	•	3.20	2.8
RF-18b	•	•	3.46	3.0
RF-18c	0.223	•	2.64	2.0
RF-18d	•	•	3.87	5.6
RF-19a	0.759	0.514	0.698	2.0
RF-19b	2.13	1.46	1.98	2.2
RF-19c	0.862	0.730	0.704	2.9
RF-19d	0.935	0.465	0.763	9.8
RF-20a	0.291	0.0075	2.61	2.9
RF-20b	1.458	•	9.80	9.8
RF-20c	0.0989	0.0053	1.75	1.9
RF-20d	•	•	3.77	3.5
RF-21a	0.241	0.277	0.226	0.74
RF-21b	1.08	1.30	1.02	3.4
RF-21c	0.0879	0.0623	0.0621	0.21
RF-21d	0.525	0.373	0.368	1.3
RF-22a	1.81	•	1.21	2.9
RF-22b	2.00	•	1.23	1.6
RF-22c	1.07	0.555	0.531	2.2
RF-22d	1.12	0.543	0.497	2.2
RF-23a	1.61	0.882	1.33	3.8
RF-23b	4.72	2.57	3.89	11
RF-23c	1.70	0.991	1.47	4.2
RF-23d	7.13	4.16	6.17	17

• Calculated results are slightly negative due to corrections for background concentrations.

RATIO PM10/TP ACCORDING TO SITE ID

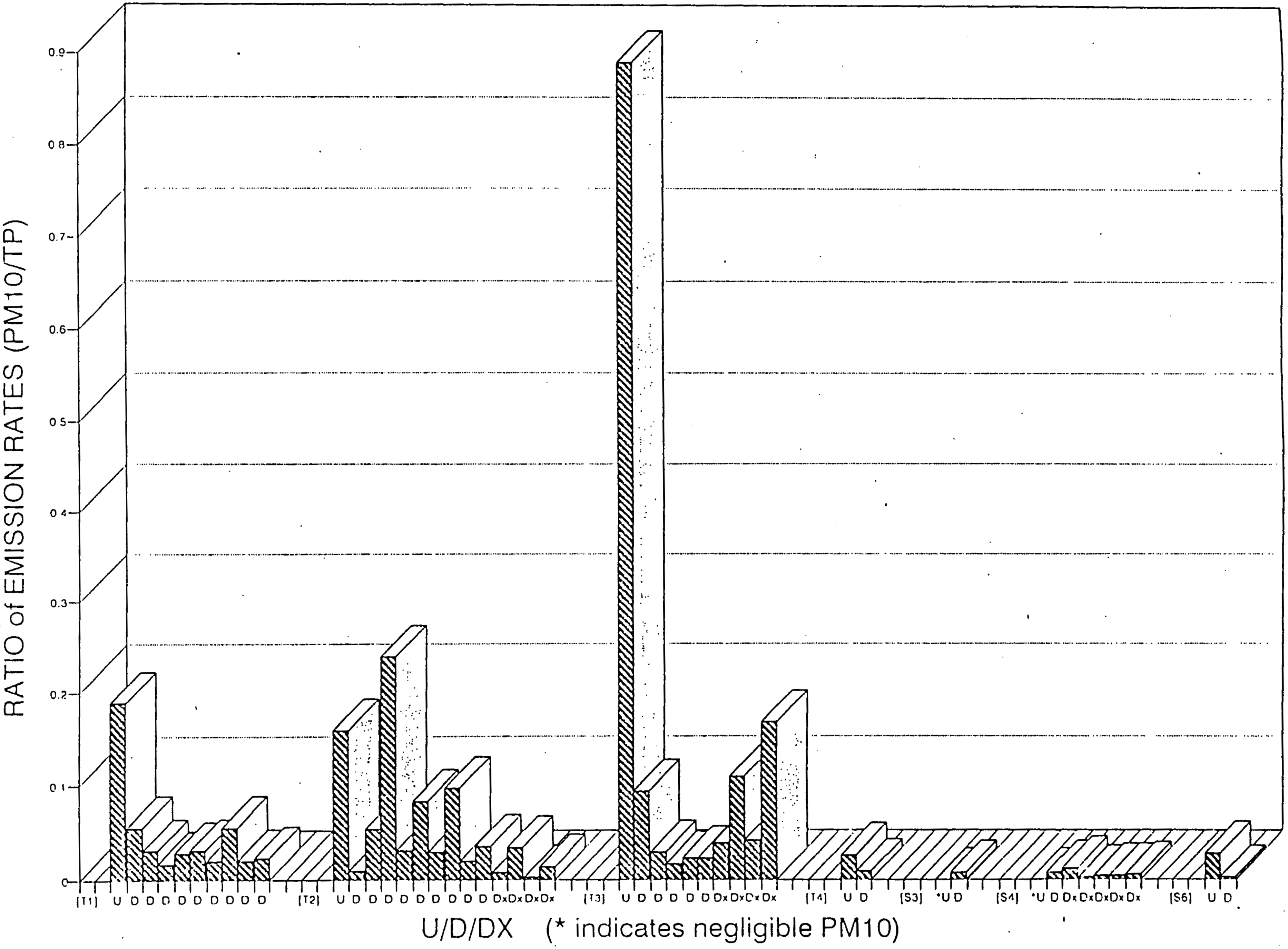

Figure 4.2 Ratio PM 10/TP

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SECTION 5

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Quality Assurance Audit

An initial review of project records was conducted by John Kinsey and reported on January 19, 1994, to the project and quality assurance management staff. The project records were reviewed for compliance to the quality assurance procedures presented in the RFI/RI Final Work Plan, dated April 23, 1993. In this review, no checks of data entry, data transfer, or calculations were made. However, Mr. Kinsey was advised that a complete example calculation had been completed by the project staff. The items reviewed and their associated procedures are listed below.

- BGI orifice calibration (EPA-600/4-77-027a and SOP EET-620)
- Sampler flow rate calibration
- Filter handling and analysis procedures (SOP EET-610)
- Sample tracking
- Data system validation

The review was audited by Carol Green on January 21, 1994. Several types of records, not located during the initial review, were located and reviewed. Based on this audit, no major problems were found. The results for each item reviewed are provided below.

<u>BGI Orifice</u>. The BGI orifice was used as a flow transfer standard. It was to have been calibrated against a Roots meter upon receipt and annually. Both the Roots meter and the orifice were calibrated by the manufacturer on June 10, 1992. Therefore, the device met the yearly calibration requirement for the June testing but not the July testing. A 1-month difference in the calibration time is not expected to have an impact on the accuracy.

<u>Sampler Flow Rate</u>. The sampler flow rate calibration for the two particulate samplers was performed in the field just before sampling, as required. The calibration

was also performed after the June testing and before the July testing. The last two calibration curves were used for the June testing and the July testing, respectively.

Filter Handling and Analysis. The calibration was conducted as required for the temperature and relative humidity devices in the constant temperature/humidity room that was used to equilibrate and weigh the 8- × 10-in filters and greased 4- × 5-in impactor substrates, before and after exposure. The balance used to weigh the items was also properly calibrated.

The only apparent deviation from the SOP requirements was that the filters were not packaged in glassine envelopes for shipment to the field. However, this SOP requirement was not appropriate for this type of work. The standard procedure is to package the items as described below, then ship the items to the field.

1. The 8- × 10-in filters are placed in numbered file folders.

2. The substrates are separated by wood and cardboard spacers, stacked, then placed in plastic carriers.

Glassine envelopes are used only to ship the exposed filters back to the laboratory. The substrates are returned to the laboratory in the plastic carriers.

Sample Tracking. Sample tracking was to be performed using field logsheets. Although this system was not used, each filter had a unique number, and the number was placed on the run sheets. Thus, the only information missing was the exact times of unloading from the sampler and storing in the field.

Data System Validation. A detailed sample calculation was provided by project staff as proof of validation.

APPENDIX B

RESULTS OF GRAVIMETRIC ANALYSIS

RESULTS OF GRAVIMETRIC ANALYSIS[a]

Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-1 6/3/93	Cyclone	9333003	3287.65	3289.40	1.75	1.90
	Blank (8 × 10)	9333008	3292.15	3292.00	−0.15	—
	Background	9333001	3277.10	3282.00	4.90	5.05
RF-2 6/3/93	Cyclone	9333004	3297.40	3311.75	14.35	14.50
	Blank (8 × 10)	9333008	3292.15	3292.00	−0.15	—
	Background	9333001	3277.10	3282.00	4.90	5.05
RF-3 6/4/93 *Cancelled on 6/3/93*	Cyclone	9333012; 9333013 (not used)	3278.70 3265.55	3279.75 -0-	1.05 -0-	1.73 —
	Blank (8 × 10)	9333009	3252.20	3252.05	−0.15	—
	Background	9333007	3276.00	3315.70	39.70	40.37
RF-4 6/4/93	Cyclone	9333011	3248.30	3283.65	35.35	36.02
	Background	9333007	3276.00	3315.70	39.70	40.37
RF-5 6/4/93	Cyclone	9333010	3232.90	5458.00	2225.10	2225.78
	Blank (8 × 10)	9333002	3264.40	3263.20	−1.20	—
	Background	9333006	3309.10	3337.05	27.95	28.63
RF-6 6/5/93	Background	9333018	3261.85	3287.45	25.60	25.70
	Blank (8 × 10)	9333020	3278.45	3278.35	−0.10	—
	Blank substrate	9338048	1484.30	1485.35	1.05	—
	Blank substrate	9338049	1499.60	1500.40	0.80	—
RF-6a 6/5/93	Cyclone	9333023	3271.60	3277.65	6.05	6.15
	Stage 1	9338056	1495.00	1502.25	7.25	6.32
	Stage 2	9338057	1488.60	1500.05	11.45	10.53
	Stage 3	9338058	1493.15	1499.30	6.15	5.22
RF-6b 6/5/93	Cyclone	9333014	3245.95	3247.90	1.95	2.05
	Stage 1	9338059	1504.70	1507.15	2.45	1.53
	Stage 2	9338060	1495.10	1498.60	3.50	2.58
	Stage 3	9338029	1468.20	1470.00	1.80	0.87
RF-6c 6/5/93	Cyclone	9333024	3235.50	3264.45	28.95	29.05
	Stage 1	9338053	1496.85	1546.15	49.30	48.38
	Stage 2	9338054	1489.50	1552.20	62.70	61.78
	Stage 3	9338055	1497.55	1519.70	22.15	21.23

Gravimetric Results (continued)

Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-6d 6/5/93	Cyclone	9333025	3346.20	3411.60	65.40	65.50
	Stage 1	9338050	1467.15	1568.65	101.50	100.58
	Stage 2	9338051	1468.10	1544.00	75.90	74.98
	Stage 3	9338052	1478.20	1507.85	29.65	28.72
RF-7 6/5/93	Cyclone	9333021	3224.40	3227.70	3.30	3.40
	Blank (8 × 10)	9333026	3352.25	3352.15	−0.10	—
	Background	9333027	3226.95	3231.85	4.90	5.00
RF-8 6/6/93	Cyclone	9333030	3369.70	3372.80	3.10	2.90
	Blank (8 × 10)	9333029	3357.90	3358.10	0.20	—
	Background	9333028	3284.65	3292.00	7.35	7.15
RF-9 6/6/93	Cyclone	9333016	3243.35	3249.45	6.10	5.90
	Blank (8 × 10)	9333029	3357.90	3358.10	0.20	0.20
	Background	9333017	3237.85	3241.10	3.25	3.05
RF-10 6/7/93	Cyclone	9333034	3248.05	3284.30	36.25	35.90
	Blank (8 × 10)	9333033	3287.80	3288.15	0.35	—
	Background	9333035	3263.40	3268.00	4.60	4.25
RF-11 6/9/93	Cyclone	9333032	3261.05	3262.55	1.50	1.08
	Blank (8 × 10)	9333022	3244.20	3244.45	0.25	—
	Background	9333031	3234.15	3240.10	5.95	5.53
RF-12 6/9/93	Cyclone	9333037	3288.60	3293.20	4.60	4.18
	Blank (8 × 10)	9333022	3244.20	3244.45	0.25	—
	Background	9333050	3261.30	3276.10	14.80	14.38
RF-13 6/9/93	Background	9333050	3261.30	3276.10	14.80	14.38
	Blank (8 × 10) 1	9333047	3237.75	3237.95	0.20	—
	Blank (8 × 10) 2	9333049	3302.10	3302.90	0.80	—
	Blank substrate	9338041	1493.50	1493.85	0.35	—
RF-13a 6/9/93	Cyclone	9333042	3275.75	3276.40	0.65	0.23
	Stage 1	9338035	1492.80	1494.75	1.95	1.60
	Stage 2	9338036	1495.25	1496.75	1.50	1.15
	Stage 3	9338037	1496.70	1498.15	1.45	1.10

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Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-13b 6/9/93	Cyclone	9333041	3289.80	3290.55	0.75	0.33
	Stage 1	9338038	1493.70	1495.20	1.50	1.15
	Stage 2	9338039	1489.40	1490.75	1.35	1.00
	Stage 3	9338040	1495.70	1497.20	1.50	1.15
RF-13c 6/9/93	Cyclone	9333040	3213.25	3213.75	0.50	0.08
	Stage 1	9338042	1468.60	1469.30	0.70	0.35
	Stage 2	9338043	1472.90	1473.70	0.80	0.45
	Stage 3	9338044	1482.55	1483.45	0.90	0.55
RF-13d 6/9/93	Cyclone	9333039	3246.85	3247.75	0.90	0.48
	Stage 1	9338045	1485.55	1486.55	1.00	0.65
	Stage 2	9338046	1484.60	1485.90	1.30	0.95
	Stage 3	9338047	1476.90	1478.15	1.25	0.90
RF-14 6/10/93	Cyclone	9333051	3277.75	3278.80	1.05	0.70
	Blank (8 × 10)	9333053	3307.40	3307.75	0.35	–
	Background	9333052	3303.85	3311.40	7.55	7.20
RF-15 6/10/93	Cyclone	9333048	3285.20	3288.45	3.25	2.90
	Blank (8 × 10)	9333053	3307.40	3307.75	0.35	–
	Background	9333052	3303.85	3311.40	7.55	7.20
RF-16 6/10/93	Cyclone	9333015	3219.25	3221.10	1.85	1.55
	Blank (8 × 10)	9333038	3242.10	3242.40	0.30	–
	Background	9333036	3264.55	3272.85	8.30	8.00
RF-17 6/10/93	Cyclone	9333019	3270.00	3279.10	9.10	8.80
	Blank (8 × 10)	9333038	3242.10	3242.40	0.30	–
	Background	9333036	3264.55	3272.85	8.30	8.00
RF-18 7/8/93	Blank (8 × 10)	9333059	3367.45	3367.85	0.40	–
	Background	9333061	3396.15	3407.50	11.35	10.95
	Blank substrate	9338004	1505.10	1505.85	0.75	–
	Blank substrate	9338005	1506.50	1507.40	0.90	–
RF-18a 7/8/93	Stage 1	9338018	1500.10	1500.95	0.85	0.08
	Stage 2	9338019	1501.00	1501.80	0.80	0.03
	Stage 3	9338020	1472.70	1473.45	0.75	−0.02
	Back-up	9333062	3343.20	3344.30	1.10	0.70

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Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-18b 7/8/93	Stage 1	9338018	1500.10	1500.95	0.85	0.08
	Stage 2	9338019	1501.00	1501.80	0.80	0.03
	Stage 3	9338020	1472.70	1473.45	0.75	−0.02
	Back-up	9333062	3343.20	3344.30	1.10	0.70
RF-18c 7/8/93	Stage 1	9338015	1506.45	1507.15	0.70	−0.07
	Stage 2	9338016	1480.90	1481.80	0.90	0.13
	Stage 3	9338017	1508.95	1509.70	0.75	−0.02
	Back-up	9333063	3417.85	3419.25	1.40	1.00
RF-18d 7/8/93	Stage 1	9338015	1506.45	1507.15	0.70	−0.07
	Stage 2	9338016	1480.90	1481.80	0.90	0.13
	Stage 3	9338017	1508.95	1509.70	0.75	−0.02
	Back-up	9333063	3417.85	3419.25	1.40	1.00
RF-19 7/9/93	Blank (8 × 10)	9333060	3355.75	3356.20	0.45	–
	Background	9333058	3348.50	3353.10	4.60	4.15
	Blank substrate	9338003	1503.55	1504.25	0.70	–
RF-19a 7/9/93	Stage 1	9338012	1501.50	1504.90	3.40	2.70
	Stage 2	9338013	1515.75	1521.55	5.80	5.10
	Stage 3	9338014	1490.70	1494.90	4.20	3.50
	Back-up	9333064	3381.55	3386.75	5.20	4.75
RF-19b 7/9/93	Stage 1	9338012	1501.50	1504.90	3.40	2.70
	Stage 2	9338013	1515.75	1521.55	5.80	5.10
	Stage 3	9338014	1490.70	1494.90	4.20	3.50
	Back-up	9333064	3381.55	3386.75	5.20	4.75
RF-19c 7/9/93	Stage 1	9338009	1502.75	1505.45	2.70	2.00
	Stage 2	9338010	1475.60	1480.40	4.80	4.10
	Stage 3	9338011	1492.50	1495.25	2.75	2.05
	Back-up	9333065	3366.10	3369.90	3.80	3.35
RF-19d 7/9/93	Stage 1	9338009	1502.75	1505.45	2.70	2.00
	Stage 2	9338010	1475.60	1480.40	4.80	4.10
	Stage 3	9338011	1492.50	1495.25	2.75	2.05
	Back-up	9338065	3366.10	3369.90	3.80	3.35

Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-20 7/9/93	Background	9333057	3384.15	3394.70	10.55	10.35
	Blank (8 × 10)	9333056	3365.50	3365.70	0.20	–
	Blank substrate	9338006	1493.15	1493.65	0.50	–
	Blank substrate	9338027	1500.35	1501.55	1.20	–
RF-20a 7/9/93	Stage 1	9338021	1501.55	1502.55	1.00	0.68
	Stage 2	9338022	1452.70	1453.25	0.55	0.23
	Stage 3	9338023	1498.80	1499.15	0.35	0.03
	Back-up	9333046	3282.65	3284.60	1.95	1.75
RF-20b 7/9/93	Stage 1	9338021	1501.55	1502.55	1.00	0.68
	Stage 2	9338022	1452.70	1453.25	0.55	0.23
	Stage 3	9338023	1498.80	1499.15	0.35	0.03
	Back-up	9333046	3282.65	3284.60	1.95	1.75
RF-20c 7/9/93	Stage 1	9338024	1493.00	1493.25	0.25	−0.07
	Stage 2	9338025	1493.35	1493.80	0.45	0.13
	Stage 3	9338026	1484.30	1484.65	0.35	0.03
	Back-up	9333045	3271.35	3273.20	1.85	1.65
RF-20d 7/9/93	Stage 1	9338024	1493.00	1493.25	0.25	−0.07
	Stage 2	9338025	1493.35	1493.80	0.45	0.13
	Stage 3	9338026	1484.30	1484.65	0.35	0.03
	Back-up	9333045	3271.35	3273.20	1.85	1.65
RF-21 7/10/93	Background	9333066	3372.20	3379.20	7.00	5.95
	Blank (8 × 10)	9333067	3333.25	3334.30	1.05	–
	Blank substrate	9338007	1471.60	1472.00	0.40	–
	Blank substrate	9338008	1478.95	1479.35	0.40	–
RF-21a 7/10/93	Stage 1	9338028	1501.70	1503.10	1.40	1.00
	Stage 2	9338030	1487.10	1488.25	1.15	0.75
	Stage 3	9338031	1489.70	1490.95	1.25	0.85
	Back-up	9333044	3258.70	3260.45	1.75	0.70
RF-21b 7/10/93	Stage 1	9338028	1501.70	1503.10	1.40	1.00
	Stage 2	9338030	1487.10	1488.25	1.15	0.75
	Stage 3	9338031	1489.70	1490.95	1.25	0.85
	Back-up	9333044	3258.70	3260.45	1.75	0.70

Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
RF-21c 7/10/93	Stage 1	9338032	1493.65	1495.50	1.85	1.45
	Stage 2	9338033	1499.30	1501.75	2.45	2.05
	Stage 3	9338034	1471.95	1473.80	1.85	1.45
	Back-up	9333043	3260.15	3262.65	2.50	1.45
RF-21d 7/10/93	Stage 1	9338032	1493.65	1495.50	1.85	1.45
	Stage 2	9338033	1499.30	1501.75	2.45	2.05
	Stage 3	9338034	1471.95	1473.80	1.85	1.45
	Back-up	9333043	3260.15	3262.65	2.50	1.45
RF-22 7/10/93	Background	9333073	3352.90	3367.40	14.50	13.72
	Blank (8 × 10)	9333067	3333.25	3334.30	1.05	—
RF-22a 7/10/93	Stage 1	9338077	1478.90	1480.80	1.90	1.11
	Stage 2	9338083	1504.90	1506.20	1.30	0.51
	Stage 3	9338070	1488.70	1488.70	0.00	−0.79
	Back-up	9333077	3324.60	3325.75	1.15	0.38
RF-22b 7/10/93	Stage 1	9338077	1478.90	1480.80	1.90	1.11
	Stage 2	9338083	1504.90	1506.20	1.30	0.51
	Stage 3	9338070	1488.70	1488.70	0.00	−0.79
	Back-up	9333077	3324.60	3325.75	1.15	0.38
RF-22c 7/10/93	Stage 1	9338088	1477.65	1478.85	1.20	0.41
	Stage 2	9338089	1490.80	1492.75	1.95	1.16
	Stage 3	9338090	1494.45	1495.85	1.40	0.61
	Back-up	9333076	3361.85	3363.25	1.40	0.63
RF-22d 7/10/93	Stage 1	9338088	1477.65	1478.85	1.20	0.41
	Stage 2	9338089	1490.80	1492.75	1.95	1.16
	Stage 3	9338090	1494.45	1495.85	1.40	0.61
	Back-up	9333076	3361.85	3363.25	1.40	0.63
RF-23 7/10/93	Background	9333073	3252.90	3367.40	14.50	13.73
	Blank (8 × 10)	9333067	3333.25	3334.30	1.05	—
	Blank (8 × 10)	9333072	3368.95	3369.45	0.50	—
RF-23a 7/10/93	Stage 1	9338091	1483.95	1490.70	6.75	5.96
	Stage 2	9338092	1491.75	1507.00	15.25	14.46
	Stage 3	9338093	1478.40	1487.10	8.70	7.91

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Test ID No.	Filter/ Substrate	ID No.[b]	Filter tare weight (mg)	Filter final weight (mg)	Weight difference (mg)	Blank-corrected weight (mg)
	Back-up	9333075	3374.15	3386.85	12.70	11.92
RF-23b 7/10/93	Stage 1	9338091	1483.95	1490.70	6.75	5.96
	Stage 2	9338092	1491.75	1507.00	15.25	14.46
	Stage 3	9338093	1478.40	1487.10	8.70	7.91
	Back-up	9333075	3374.15	3386.85	12.70	11.92
RF-23c 7/10/93	Stage 1	9338094	1490.40	1507.25	16.85	16.06
	Stage 2	9338095	1492.85	1534.60	41.75	40.96
	Stage 3	9338096	1483.70	1508.40	24.70	23.91
	Back-up	9333074	3362.25	3398.45	36.20	35.42
RF-23d 7/10/93	Stage 1	9338094	1490.40	1507.25	16.85	16.06
	Stage 2	9338095	1492.85	1534.60	41.75	40.96
	Stage 3	9338096	1483.70	1508.40	24.70	23.91
	Back-up	9333074	3362.25	3398.45	36.20	35.42
•	4 × 5	9338068	1494.95	1493.45	1.50	—
•	4 × 5	9338069	1495.15	1493.85	1.30	—
•	4 × 5	9338071	1494.40	1493.80	0.60	—
•	4 × 5	9338072	1493.50	1492.85	0.65	—
•	4 × 5	9338073	1488.75	1488.40	0.35	—
•	4 × 5	9338097	1470.00	1469.10	0.90	—

[a] "Cyclone" refers to the 8 × 10 backup filter beneath the cyclone; "stage x" refers to the 4 × 5 substrate for impactor stage x.

[b] If the ID No. begins with 9333, it refers to an 8 × 10 filter; if it begins with 9338, it refers to a 4 × 5 substrate.

• A geometric mean of these substrate blank weights was used to blank correct the substrate weight gains from the testing on 7/10/93, at Site T3.

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CYCLONE CATCHES

Run No.	Particulate Weight[a] (grams)
RF-1	0.0465
RF-2	6.7802
RF-3	0.0586
RF-4	4.2923
RF-5	184.3490
RF-6a	7.1899
RF-6b	1.5252
RF-6c	25.9389
RF-6d	27.8369
RF-7	0.0124
RF-8	0.0313
RF-9	0.0012
RF-10	0.3372
RF-11	0.0037
RF-12	0.2734
RF-13a	0.0408
RF-13b	0.0061
RF-13c	0.0322
RF-13d	0.0218
RF-14	0.0541
RF-15	0.2148
RF-16	0.0114
RF-17	0.8653
RF-18a	0.0100
RF-18b	0.0078
RF-18c	0.0177

Run No.	Particulate Weight[a] (grams)
RF-18d	0.0107
RF-19a	0.3313
RF-19b	0.1103
RF-19c	0.2311
RF-19d	0.2099
RF-20a	0.0317
RF-20b	0.0073
RF-20c	0.0454
RF-20d	0.0196
RF-21a	0.1493
RF-21b	0.0291
RF-21c	1.1495
RF-21d	0.1836
RF-22a	0.0113
RF-22b	0.0054
RF-22c	0.0496
RF-22d	0.0386
RF-23a	0.4257
RF-23b	0.1305
RF-23c	1.1462
RF-23d	0.2277

[a] Cyclone catches were transferred to pouches that were automatically tared in the weighing process.